Synthesis
Agrobiodiversity – conservation and functionality

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Biodiversity, including that of insects, should be preserved or even enhanced for its own sake, sometimes encouraged by international obligations. In agricultural areas an additional reason for its conservation is the ecological services it can provide to agriculture, including the natural control of crop pests. In this special issue of *Entomologische Berichten* studies focusing on each of the two aims are discussed, with special attention for the arthropod groups that play a role in pest control. Both aims can partly rely on conserving and improving the network of non-productive landscape elements, but for certain goals and insect groups specific measures will be required.

Introduction

Two-thirds of the total surface of The Netherlands is used for agricultural purposes (figure 1). Traditionally, practises of nature conservation in The Netherlands (and large parts of Europe) are largely associated with the cultural landscape and so-called semi-natural areas (Bakker & Van Wieren 1995). In line with this tradition, all sorts of agri-environment schemes have been created by the government to conserve or increase biodiversity in the agricultural area (Berendse *et al*. 2004, see Box 1). Biodiversity in the agricultural landscape is not only an aim in itself, but can also provide several ecosystem services, including the natural control of pest species.

The recognised importance of biodiversity in the agricultural landscape has resulted in many studies dealing with agrobiodiversity patterns and the presence of natural predators in relation to landscape and management. In this special issue of *Entomologische Berichten*, a number of Dutch studies on these subjects are described.

1. Some parts of The Netherlands are dominated by agricultural practises, for example the Noordoostpolder. Photo: Aerodata International Surveys/Google Earth
Sommige delen van Nederland worden gedomineerd door agrarische gebruik, zoals de Noordoostpolder.

Biodiversity in the agricultural landscape

Booij et al. estimate that 3% of the Dutch insect species is strictly dependent on the agricultural area. A significantly higher diversity can be found in the (semi-)natural fragments next to the fields. Here, fewer disturbances caused by agricultural activities occur, and there is a relative wealth of (micro-)habitats, thus more space for variation, compared to the structurally poor arable fields (Tscharntke *et al*. 2002a). Several authors show that these elements, which have no direct commercial goal (but do have a clear indirect function), can indeed be rich in species. Van Achterberg illustrates this by the enormous species richness in only one coppice wood, in a fen meadow landscape. These coppice woods have their origin in the practical use of farmers, but are nowadays more or less left untouched. He found a spectacular number of Braconidae species, insects that parasitize on caterpillars and beetle and fly larvae. A high species number of these parasitoids indicates a high diversity of other insects as well. Kohler et al. did standardized samplings of flower-visiting bees and hover flies in ditch banks. The diversity and abundance appeared highly correlated with the distance to nature reserves, which again underlines the importance of other elements in the agricultural landscape. Hoffmann & Kwak studied a wide range of flower-visiting insects and found that their diversity especially depends on local plant diversity, and that plant diversity in its turn is affected by the surrounding landscape diversity. Guldemond et al. looked in depth to the bee and wasp species richness at a specific ex-perimental farm. This farm had been 'enriched' with a number of insect habitats integrated amongst the meadows. Their findings illustrate the potential entomological values of particular conservation measures in the agricultural areas.

Apart from braconids and other wasps, bees and hover flies, of course many other insect groups can be abundant in field margins, hedges and ditches. Many species have benefited from the historical transformation of forest and shrubland to (semi-natural) open ecosystems. These species benefit from the open landscape heated by direct sunlight or from the often nutrient-rich situations created by the management of the area. Many of these species are somehow dependent on the perennial vegetation in the (semi-)natural fragments as well (Thomas *et al.* 2001, Schmidt & Tscharntke 2005). For example, common agricultural practises are very detrimental for ants which have a 'sessile' way of living. The nests of almost all ant species can not survive the disturbances by manure and pesticide applications, harvest and ploughing common in arable fields or meadows (Mabelis 2002). Ants in the agricultural landscape are therefore almost entirely confined to the fragments with perennial vegetation. Insects with good dispersal abilities, for example butterflies, might cross agricultural fields, but need the natural fragments for foraging and resting (Söderstöm & Hedblom 2007, Van der Lee 2007). Many butterfly species can be found feeding on flowers in field edges. The penetrability of the large agricultural areas is dependent on the number of nectar sources and the distance between them (Steffan-Dewenter & Tscharntke 1997). Many insect and spider species can complete their life cycle in the natural fragments in the agricultural landscape – these species are however often not very critical in regard to food and shelter and most have a high dispersal and colonisation rate, or are by other means adapted to disturbances (Tscharntke *et al.* 2002b, Samu & Szinetár 2002).

Occasionally, specialist or rare species are found in the agricultural landscape. An example is the Green hawker, *Aeshna viridis* (Eversmann) (figure 2), a species appearing on the Habitat Directive of the European Union. This dragonfly has strongholds in agricultural areas with many ditches in the western part of our country (for example De Vries & Ketelaar 2003). Another spectacular and quite rare dragonfly that is able reproducing in agricultural ditches is the Banded darter, *Sympetrum pedemontanum* (Allioni) (Mensing 2002). As long as the water in the ditches is of good quality, the surroundings seemingly provide in ample opportunities for foraging, territorial settlements and mate finding for these dragonflies. The Small green bush-cricket, *Tettigonia cantans* (Fuessly), has only one localised population in The Netherlands. This site constitutes of a number of ditch banks and verges in an agricultural landscape in the province of Overijssel (Kleukers *et al.* 2004). All these species exemplify that the agricultural landscape need not be hostile as such; the existence of fragments with more natural conditions can turn these areas into highly interesting sites for a suite of insect species.

2. Some specialist species can be found in the agricultural landscape. The Green hawker, *Aeshna viridis* Eversmann, has strongholds in ditches in the agricultural fen meadow landscape in the western part of The Netherlands. Photo: N. de With
Sommige kritische soorten kunnen in het agrarische landschap worden aangetroffen. De groene glazenmaker, *Aeshna viridis*, heeft bolwerken in enkele agrarische laagveengebieden van West-Nederland.

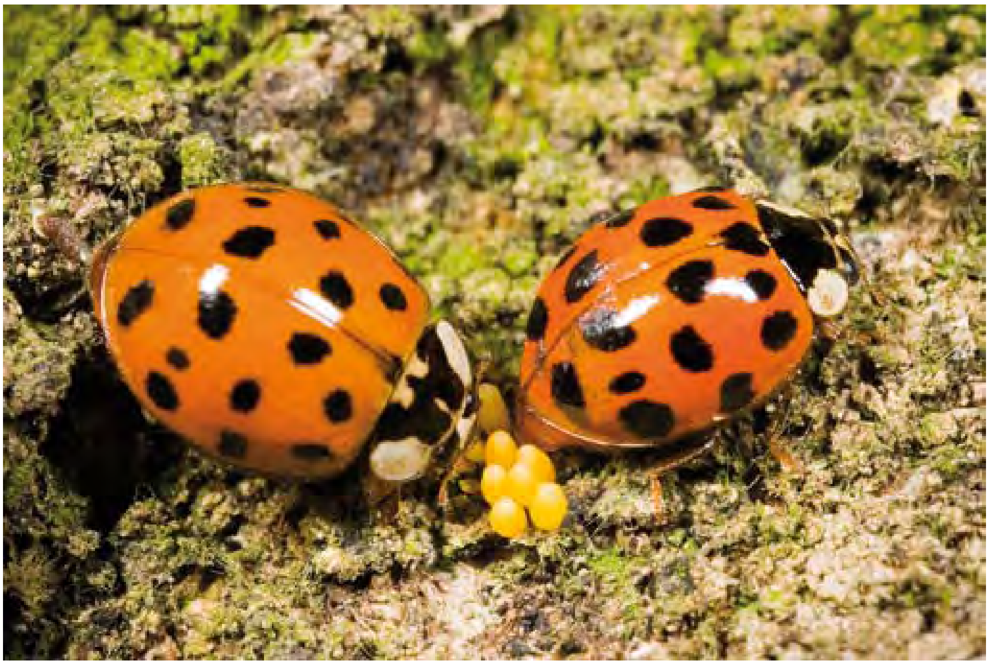
Box 1. Government policy

The Dutch agri-environment schemes to increase biodiversity in the agricultural area are derived from two governmental reports, where it is stated that the agricultural area should be relatively high in biodiversity and attractive for recreational purposes ('Natuur voor mensen, mensen voor natuur' (2000) and 'Agenda voor een Vitaal Platteland' (2004), both published by the Dutch Ministry of Agriculture, Nature and Food Quality). Farmers can either be paid for creating 'permanent' (30 years) nature on their property (and thus give up commercial farming; 'particulier natuurbeheer') or they can enter six year contracts in which they adapt the management of parts of their property. Some agri-environment schemes focus on meadow birds and flora in meadows. A few others reward the stimulation of biodiversity in so-called small habitat fragments within the agricultural landscape, for example arable field verges, hedges, ditch banks and wood lots. For example, the so-called 'Subsidy Agricultural Nature Conservation' (SAN: 'Subsidieregeling Agrarisch Natuurbeheer') rewards the creation of fauna and flora strips, to increase the diversity of plants and small animals and to enlarge landscape attractiveness for recreational purposes (LNV without date). Within the National Ecological Network, 90.000 ha of agricultural area is to be placed under agri-environment schemes to adequately protect natural and landscape values. This area is to be supplemented with 35.000 ha outside the National Ecological Network (Sanders 2002). This demonstrates the close link between the agricultural landscape and the present-day opinion on nature conservation.

Although high numbers of insects and spiders can be found on arable fields themselves, this mostly concerns pioneer species. These species are able to colonise the sites after disturbances or after hibernation elsewhere (Takahashi 1993, Sotherton 1995, Dennis *et al.* 2000). It seems that only a limited number of species are able to complete their entire life cycle on arable fields. Life cycle completion in such fields requires that, for instance, the soil is left untouched during the larval or diapause period, or that grassy areas are available year-round and that ploughing is not common practise. Examples of species that can complete their life cycle here are some ground beetles (Carabidae), rove beetles (Staphylinidae) and leather-jackets (Tipulidae) (Linzell & Madge 1986, Saska *et al.* 2007). However, generally these species are poorly studied. Booij et al. rightly state that more studies on such truly *agricultural species* are urgently needed.

Natural control of pest species

Classic biological control – that is, the introduction of species that prey on harmful species into certain areas – has been, and still is, widely applied (DeBach 1964). These introductions can lead to establishment of exotic species, which may have undesirable effects on indigenous species compositions and ecosystem functioning (Alyokhin & Sewell 2004). An example of the successful establishment of an introduced control species is mentioned by Lommen & Cuppen: the multicoloured Asian lady bug *Harmonia axyridis* (Pallas) (figure 3) is now very common in The Netherlands. Rather than introducing allochtonous species, the promotion of site characteristic (and indigenous) insects and spiders is a much saver practise to increase the predation



3. The multicoloured Asian lady bug *Harmonia axyridis* (Pallas) was introduced for biological control, but nowadays its occurrence in the wild can be described as a pest. Photo: Th. Heijerman
Het veelkleurig Aziatisch lieveheersbeestje, *Harmonia axyridis*, een voor de biologische bestrijding geïntroduceerde soort, waarvan het voorkomen tegenwoordig als een pest kan worden omschreven.

on pest species (Kajak & Łukasiewicz 1994, Van Lenteren *et al.* 2003); this approach is referred to as natural control (or conservation biological control; Barbosa 2002).

For the purpose of natural control, biodiversity in the agricultural landscape is the basic material. A diverse fauna may provide additional services as well, such as pollination, the fertilization and aeration of soils, reduction of erosion and esthetical and recreational values (Tilman *et al.* 1999, Pascuala & Perrings 2007).

Landscape perspective

Different spatial scales play a role in the application and stimulation of natural enemies that are already present in the vicinity of a field (see also Thies & Tscharntke 1999). Den Belder et al. demonstrate that landscapes with a tighter network of hedgerows and smaller arable fields are better suited for natural pest control: caterpillar densities of the Small white, *Pieris rapae* (Linnaeus), and Diamondback moth, *Plutella xylostella* (Linnaeus), in Brussels sprout fields are lower if the surrounding landscape has more hedgerows or other linear elements ('veins') and if other fields are fragmented more; this effect can be found at distances up to one km from the focal cabbage field. Likewise, Kohler et al. show that the presence of the aphid-predating syrphid fly *Melanostoma mellinum* (Linnaeus) drops with increasing distance to nature reserves in the surroundings.

The effects reported by Den Belder et al. are based on field data of herbivore abundance. Baveco & Bianchi make a step up the trophic ladder and measure the parasitisation and predation of the herbivores. Moreover, they describe novel mathematical methods to quantify the impact of landscape structures on natural control. This approach helps in drawing more general conclusions that go beyond the limitations of a specific experiment. In the end it may help to predict the optimal composition of agricultural landscapes, to achieve (natural) pest control in a particular field. Van der Werf & Bianchi's simulation models proof very handy in exploring the influence of specific shapes and sizes of natural elements in the landscape on pest control. Such theoretical studies are instrumental in the exploration of key features in the interaction between prey, natural enemies and landscape elements, and their outcomes/predictions should be taken as handles for additional field experiments with real organisms.

On a smaller spatial scale, especially field margins (figure 4) seem to have a positive effect on the number of predators and predator species in the adjacent fields, whereby the age of the vegetation seems an important factor in determining the abundance of predators (Denys & Tscharntke 2002). This positive effect can come about in a variety of ways. Since fields are usually barren in winter, the grassy edges are excellent sites for hibernation (Van Alebeek et al.). Throughout the season field margins can offer additional prey when pest levels are still low. In addition, flowering field margins provide pollen and nectar which is especially important for those natural enemies that do not feed on prey in the winged (adult) stage (Van Rijn & Wäckers).

Field margins only have a net positive effect on pest suppression in the field, if the positive effect of the flowers on natural enemies outweighs their effect on the pest species (Van Rijn & Wäckers). After all, the creation of perennial fragments may also increase the number of pest species (Zhao 1992, Baggen & Gurr 1998). Winkler *et al.* (2005) show that certain flowers that are attractive for pest species, if sufficiently abundant, may lead to an increased infestation rate of the crops as well (figure 5).

4. Field margins with perennial vegetation can provide a natural supply of predatory insects and spiders, which can have a negative effect on pest species. Photo: P. van Rijn
Akkerranden met overblijvende vegetatie kunnen zorgen voor een natuurlijk voorziening van predatoire insecten en spinnen, die een negatief effect kunnen hebben op plaagsoorten.

5. Brown knapweed *Centaurea jacea* in flowery strips might increase the infestation rate of small white *Pieris rapae* (Linnaeus) caterpillars in adjacent sprout fields. Photos: J. Noordijk
Echt knoopkruid (*Centaurea jacea*) in bloemrijke akkerranden kan de infectiedichtheid van rupsen van het klein koolwitje (*Pieris rapae*) in aanliggende spruitakkers vergroten.

Similarly, some bug species are known to colonise agricultural fields from nearby road verges or wood lots (Loomans & Scholte).

On the smallest spatial scale pest levels may even be affected by the plants that grow right next to the crop plants (Bukovinszky & Van Lenteren). However, the effects of intercropping are difficult to predict, and the design of 'multicrop systems that work' requires detailed studies of the key insect species.

On a similar spatial scale, natural enemies can obviously be affected by agricultural practices, such as ploughing, fertilising and pesticide application. The use of organic fertilisers or green manure, rather than mineral fertilisers, will benefit the saprophytic organisms that feed on organic matter. These organisms in their turn may have a beneficial effect on ground-dwelling predators, simply by providing (additional) food (Smeding & De Snoo 2003, Schmidt *et al*. 2004). Changing the soil microbial community may even affect a plant's resistance against herbivores (Hol). A reduced use of pesticides is not only the main aim but also the main means of agrobiodiversity projects (Van Alebeek et al.). The benefits of a varied landscape may only translate into higher numbers of natural enemies if the use of pesticides is limited to (1) selective substances with minimal harm on natural enemies, and (2) moments when actual field sampling data indicate its necessity, as opposed to calendar-based preventive sprays (Drukker, Van Alebeek et al.).

6. The larvae of some hover flies (in this case *Sphaerophoria rueppelli* (Wiedemann)) feed on aphids and thereby contribute to their control. Photo: J. Noordijk
De larven van sommige zweefvliegen (in dit geval *Sphaerophoria rueppelli*) eten bladluizen en dragen zo bij aan populatieonderdrukking.

Species perspective

A wide range of pest species is found on agricultural crops. Loomans & Scholte discuss seven major groups of pest species, among them aphids, whiteflies, bugs, caterpillars, mites and thrips. The great diversity paints the necessity to suppress these pests with a variety of natural predators. Several authors emphasize the specific feeding methods, periods of activity and modes of colonisation of the most effective (indigenous) predators. Spiders, lacewings, earwigs, ground beetles, ladybird beetles, hoverflies, galling midges, predatory bugs and parasitoid wasps all have different effects on (potential) pests (figure 6). They also differ in habitat requirements that should be taken into account when designing measures to improve natural control. In addition to these groups, some other insects, which have not been given much attention in this issue, can also be effective in natural control, for example rove beetles (Staphylinidae), parasitoid flies (Tachinidae), and predatory mites (Phytoseiidae). All these predators not only affect their prey, they also influence each other, either directly, when they co-occur (intra-guild predation), or indirectly, via the feeding on a mutual prey (competition) or via avoidance of a distantly spotted competitor; the total effect of all these predators together is definitely not equal to the sum of their separate effects (Casula *et al*. 2006, Janssen *et al*. 1998, Sih *et al*. 1998). Such interactions may sometimes decrease the effectiveness of natural enemies (Rosenheim 1998), but a diversity of predators and parasitoids can also have positive impacts on pest control (Altieri 1999, Tscharntke *et al*. 2005).
The different natural enemies may be *complementary*, for

example attack different stages of the pest species, be more active under different conditions or in different periods of the year. This may reduce the chance of herbivores remaining unnoticed (Wilby & Thomas 2002). In some cases, the impact of the different natural enemies may even be *synergistic*, as shown for ground-dwelling and leaf-dwelling predators of aphids (Losey & Denno 1998). In the latter example carabid beetles kill the aphids that drop from the plants in response to ladybird beetles, leaving the aphids no room for escape. A high diversity of natural enemy groups on and around the agricultural fields may decrease the chance of a new herbivore species to become a pest, the predators forming a biological buffer (Hooper *et al*. 2006). However, the number and type of species-species interactions in such a complex system are plenty and it is by no means clear what the end result is going to be. It seems only likely that the outcome is not only dependent on species and system characteristics but on starting conditions and local circumstances as well. The complexity of system should not discourage us, but rather motivate us to continue our investigations. This issue of *Entomologische Berichten* ties together a whole lot of information – it would be great if it would stimulate the further exploration of this rich and fascinating field.

Conclusion

Conservation and utilisation of agrobiodiversity may very well go hand-in-hand. Conservation will often also improve the conditions for beneficial natural enemies and other ecosystem services. Specific measures to enhance natural control or 'functional biodiversity' (such as field margins) will generally increase the possibilities for many other non-beneficial species as well. Semi-natural landscape elements not only harbour a great diversity of species, but also play a role in maintaining populations of beneficial insects in the agricultural landscape. Combining the conservation and function oriented approaches to agrobiodiversity may broaden the acceptance of the costs that are often involved, especially when this results in a more diverse and interesting landscape that encourages exploration and recreation. However, the specific needs of certain groups of insects (natural enemies as well as conservation groups) may urge us to go beyond general landscaping and to take specific measures. The necessity and effectiveness of such measures can often only be revealed by specific studies of entomologists and ecologists.

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Samenvatting

Agrobiodiversiteit - natuurbeschermingsaspecten en functionaliteit
Biodiversiteit - ook die van insecten - dient, onder andere vanwege internationale verplichtingen, behouden en zelfs bevorderd te worden. In landbouwgebieden kan het behouden en bevorderen van biodiversiteit niet alleen een doel op zich zijn, maar kan het ook functioneel zijn, bijvoorbeeld in de vorm van de natuurlijke bestrijding van plagen. In dit themanummer van *Entomologische Berichten* worden Nederlandse studies besproken die op beide biodiversiteitsdoelen betrekking hebben, met extra nadruk op de groepen insecten en spinnen die een rol spelen bij de natuurlijke plaagbestrijding. Beide doelen kunnen bevorderd worden door behoud en algemene verbetering van de netwerken van niet-productieve landschapselementen (de 'groenblauwe dooradering'). Voor bepaalde doelen en doelorganismen zijn echter specifieke maatregelen noodzakelijk. Alleen door gericht onderzoek is te achterhalen wanneer dit nodig is en welke maatregelen doeltreffend zijn.

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